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Seasonal variations in the length-weight relationship and relative condition factor of Bombay duck, *Harpadon nehereus* (Hamilton, 1822) (Aulopiformes : Synodontidae) inhabiting the marine area of the west coast of India

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Harpadon nehereus (Hamilton, 1822), commercially known as Bombay duck and is locally named as 'Bumla' or 'Bombil' along the western coast of India. The area between northern geographical coordinates of 18° and 22° N represents intermittent fishery resources with discontinuous distribution, and the majority of the resources are caught by the 'dol net'. The present study revealed information on 1523 specimens of Bombay duck, which were used for the analysis of length-weight relationship (LWR), and condition factor (K) collected from various fishing villages of west coast of India during September 2014 to November 2016. The results indicated that females bear longer and heavier body sizes than males. The analysis of LWR shows exponent 'b' values of 3.03 for males indicating isometric growth and female (3.10) establish growth as positive allometric (b > 3). A significant dissimilarity is observed in 'b' values among the seasons for Bombay duck ($P < 0.05$). The 'b' value was highest during summer (3.37), followed by winter (3.22), autumn (3.20), and monsoon season showed the lowest value, *i.e.*, 2.95, indicating higher growth during the summer season in terms of weight. The Kn value observed in the present investigation was 1.02 ± 0.21. Information from the field for this species is rare, and the outcomes of the present study will help the administration in conservation of *H. nehereus* fishery in its natural range.

[**Keywords**: Bombay duck, India, Kn, Length, Seasonal, Weight]

Introduction

Fish stocks are typically administered through fisheries management using several crucial steps by the oceanic countries. However, fisheries are continue to collapse in few regions of the world, even though several attempts have been made to preserve the marine environment in healthy conditions and to protect together fisheries biomass[1]. Vital research instruments and managers integrate the biometric analysis that conveys facts on fish species for an assumed their biomass evaluation[2]. Biometric observations are used to determine the developmental attributes diagnosed with fish weight and length[3], as the species gets affected by numerous ecological and biotic factors apart from the state of prosperity. The length-weight relationship (LWR) in fish been highlighted through various studies with an output of significant findings. Such findings provide information about the pattern for growth, life history, the fatness of fish, general wellbeing, habitat condition[4], and additionally on morphological attributes of the fish[5].

India endowed with a long coastline of 8119 km, with a 0.5 million km^2 continental shelf and wide EEZ (2.02 million km^2). The marine fish landing along the Indian coastline in 2017 was calculated as 3.83 million tons (t), demonstrating an expansion by about 5.6 % compared with the landings in 2016. To this, pelagic finfishes contributed 54 % of the total marine fish landings in 2017. Indian oil sardine, Bombay duck, lesser sardines, mackerel, and ribbon fish contributed nearly 60 % to the pelagic fish landings. The estimated catch of Bombay duck was 76573.87 t, recording a decline of 18 % to the earlier year landings. Bombay duck catch landings represented 9.74 % and 27.16 % of the total landings and the pelagic landings, respectively during 2017. Mechanized dol net was the significant fishing gear contributing about 95 % towards Bombay duck catches[6]. *Harpadon nehereus* (Hamilton, 1822) belonging to the family Synodontidae, class Actinopterygii[7], is popularly known as Bombay duck inhabits the shallow inshore waters, including the Bay of Bengal, and estuarine areas of the Arabian Sea. It is

locally known as 'Bumla' or 'Bombil' along the western part of the Indian coastline and exhibits a discontinuous distribution[8].

Earlier studies have been carried out by various authors from a different locations on LWR of *H. nehereus*[7,9-25]. It is very important to understand the relationship between the length and weight of this species in its non-critical habitat for the successful management and conservation of the natural habitat of *H. nehereus*. As a result, alongside the western coast of India, the point of detailed investigation has been vital to its natural ecosystem.

Materials and Methods

Random specimens of Bombay duck were collected from the landing centres (Jafrabad, Rajpara, and Navabander) as shown in Figure 1 throughout the sampling period from September 2014 to November 2016 and were utilized for biological examinations. A total of 1523 specimens comprising of 646 males and 789 females were used in the present study. The specimens were separated into 5 cm size class intervals for LWR analysis. The LWR method is based on the hypothesis that the size of individuals of similar cohort in a fish population likely show a normal distribution[26].

Length-weight relationship (LWR):

The length-weight relationship was calculated as $W = a\ L^b$, and the function was linearized following log transformation[27]. The parameters were estimated using the least square method taking log (TL) = X and log (TW) = Y for obtaining values of $\sum X$, $\sum x^2$, $\sum Y$, $\sum Y^2$, and $\sum XY$. The regression coefficient or the regression line (b) was calculated using the below equation as:

$$b = [\sum XY - (\sum X) * (\sum Y) / N] / [\sum X^2 - (\sum X)^2 / N]$$

The formula $a = \bar{Y} - b\,\bar{X}$ is used to obtain the intercept 'a'. The $\bar{X}$ and $\bar{Y}$ represent mean values of X and Y, respectively, and 'N' represents total number of samples. The formula used as a linear equation by transforming values into logarithmic transformation. Cren[27] reported log W = log a + b * log L or Y = A + b X was obtained from LWR data; where; W = weight (gm); L = total length (cm); constants are represented by 'a' and 'b' (Where, log a = A).

In order to determine whether the values of 'b' for males and females are significantly different from '3' using the Student's *t* - test formula, was performed utilizing equation $t = (b - B) / S_b$; where; B = 3 and S_b = standard error of 'b'.

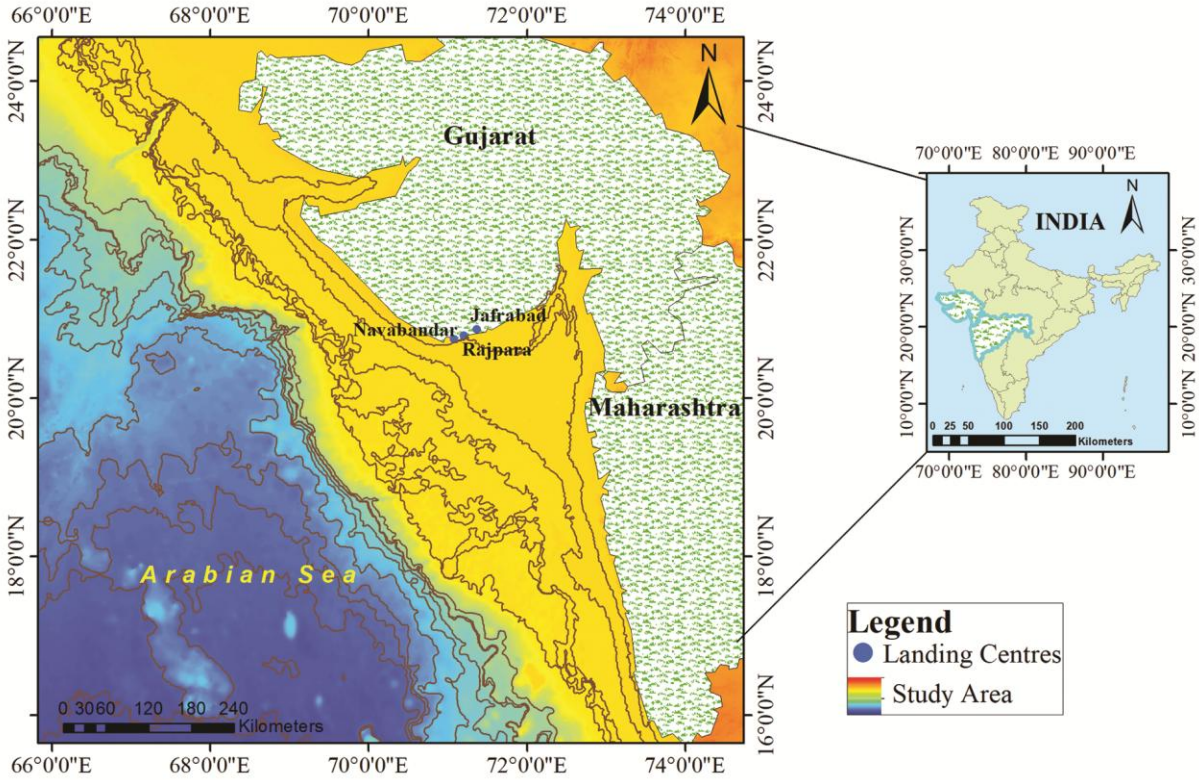

Fig. 1 — Study area and major Bombay duck fishing harbors (shaded part represents area considered for investigation)

Condition factor:

The condition factors were estimated for males, females, and for pooled data. Information was obtained for different length groups for several months to comprehend details about the prosperity of the species, reproductive behaviour, nourishing propensities, and other parameters[5]. Ponderal Index / Condition factor / Fulton's condition factor[28] was evaluated utilizing the formula: $K = 100\ W / L^3$; where, W = fish body weight (gm), and L = total fish length (cm). The relative condition factor (Kn)[28] for males and females was assessed by utilizing formula Kn = W / w (W = observed weight and w = estimated weight) analyzed from the LWR.

All information was analyzed using JMP Version 14 created via Statistical Analysis System (SAS). To measure the LWR, Gökçe *et al.*[29] used ANOVA to determine the recognised value of the regression model while $P < 0.05$ was used. The student's *t* - test correlation is checked if 'b' is not significantly the same for each group as the isometric growth criterion (b = 3). While an allometric growth of either negative or positive or ($P < 0.05$) is considered to be a factually significant difference of 'b' from 3 and where 'b' is calculated to be quite the same as 3 ($P > 0.05$) is an isometric development[30]. The relationship was calculated by linear regression of natural logarithms of length and weight data for both males and females. Fishes were grouped according to the duration after they were caught (autumn, winter, summer, and monsoon) to create LWR with understanding of seasonal changes that may have an effect on 'b' values[2].

Results

The males of the size range 105 - 320 mm (07 - 192 gm weight) and the females of the size range 119 - 351 mm (10 - 270 gm) were analyzed for computing LWR of *H. nehereus*. The parameter values of 'a' and 'b' for every one of these size classes are given in Table 1 and are also displayed as a scatter diagram for observed value of weight (g) against total length (mm) and the fitted curve separately for pooled sample data in Figure 2. The fundamental values of normality and independence were tested and validated using graphic techniques (residual plots)[31]. The seasonal variation in LWR was measured for four seasons, i.e. winter (December - March), summer (April - June), monsoon (July - September) and autumn (October - November) and is presented in Table 1.

The mean value of K was estimated to be 0.51 (female), 0.48 (male) and 0.49 (pooled), respectively (Table 2). The K values ranged from 0.60 (September 2014) to 0.38 (December 2014) for males, while the K values ranged from 0.38 (December 2014) to 0.58 (January 2015) for females. Seasonal shifts were observed as K values remained 0.48 (autumn and winter), 0.50 (summer) and 0.55 (monsoon), respectively between seasons. The Kn values for males ranged from 0.81 (December 2014) to 1.24 (September 2014) whereas in females it ranged from

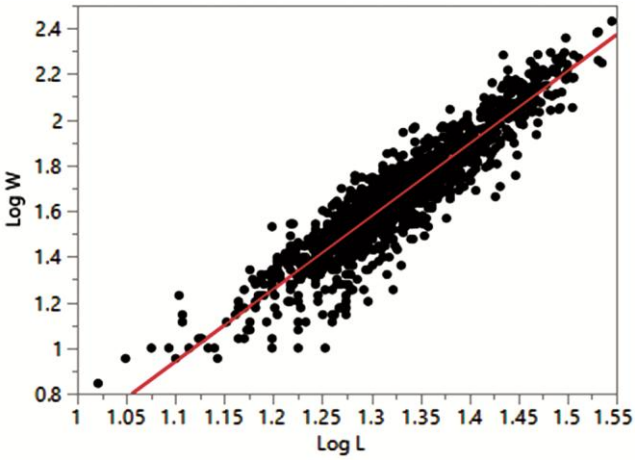

Fig. 2 — Least square regression of Bombay duck, *H. nehereus* (Pooled)

Table 1 — Detailed LWR analysis of the sexes and seasons for the Bombay duck (*H. nehereus*)

Groups / Seasons	Observed No.	Length range (cm)	Weight range (gm)	'a' value	'b' value	'r' value	r^2 value	S_b	$t = (b-3) / S_b$
Pooled	1523	10.5 - 35.1	7 - 270	0.07748	3.18034	0.92797	0.86112	0.04763	0.6469*
Male	646	10.5 - 32. 0	7 - 192	0.09411	3.03082	0.92884	0.86275	0.04165	2.5195
Female	789	11.9 - 35.1	10 - 270	0.08695	3.10494	0.93591	0.87594	0.03274	5.5069
Autumn	424	12.7 - 35.1	13 - 270	0.07369	3.20223	0.93029	0.86545	0.06824	3.1600
Winter	653	11.2 - 28 .2	9 - 119	0.07406	3.21565	0.87936	0.77327	0.10901	3.3884
Summer	266	15.6 - 29.0	13 - 119	0.06091	3.36940	0.88513	0.78347	0.06146	3.2904
Monsoon	153	15.8 - 34. 0	27 - 243	0.11114	2.94913	0.92784	0.86089	0.09647	-0.527*

(* *Not Significant at 5% and 1%*)

Table 2 — Condition factor (K) and Relative condition factors (Kn) of Bombay duck (*H. nehereus*)

Species	Sex	No.	Length range (mm)		K value range		K Value (Mean)	Kn value range		Kn value (Mean)
			Min	Max	Min	Max		Min	Max	
Bombay duck	Male	646	105	320	0.24	0.95	0.48 ± 0.09	0.50	1.99	1.02 ± 0.19
	Female	789	119	351	0.19	0.89	0.51 ± 0.10	0.39	1.78	1.02 ± 0.19
	Pooled	1523	105	351	0.17	0.95	0.49 ± 0.10	0.37	1.9	1.02 ± 0.21

0.77 (December 2014) to 0.16 (January 2015). The Kn values based on length size groups observed ranged from 0.86 to 1.34 for males and from 0.99 to 1.29 for females. In the male size groups (length) minimum Kn value reported was 0.86 (135 - 149 mm), followed by 0.94 (255 - 269 mm), 0.96 (315 - 329 mm) and 0.97 (210 - 224 mm). The minimum Kn value reported for females was 0.99 (165 - 179 mm), and the most significant mean Kn value of 1.29 was reported for the 120 - 134 mm size group (length). The significant Kn values reported for 105 - 119 mm length category were 1.34 and 1.15 for the 270 - 284 mm length category for males.

Discussion

Length-weight relationship (LWR):

A total of 1523 samples of *H. nehereus* were obtained from the west coast of India, with an M : F ratio of 0.81:1. The mean total length and weight of male were 20.88 ± 3.38 cm and 40.06 ± 28.57 gm, respectively, while the female figures were 22.24 ± 3.75 cm and 61.62 ± 38.03 gm, respectively. The data obtained indicated that females had longer and heavier sizes than males. In the present research, the proportion of males and females differed from that of other studies on Bombay duck[20,21]. Growth as isometric was indicated by exponent 'b' values for males (3.03) and growth as positive allometric (b > 3) for females (3.10). Males demonstrated growth as isometric (P > 0.05); this may be due to their phenotype specification or natural environmental conditions in the vicinity of their habitat[32]. The student's *t*-test findings suggest that the 'b' values for females and pooled data showed major differences (P < 0.05) amongst males, showing positive allometric growth.

The value of 'b' was higher in females, indicating that the cubic increase in weight was 3.10 for each unit length and was 3.03 for males. The length-weight relationship of the fish under which the fish maintain a constant shape as '3' is explained by the Cube Law. If biomass changes, it leads to fish growth and there are significant variations in isometric growth[33]. Ghosh[8] calculated the 'b' value separately for males (3.0111) and females (0.3574) off the coast of Saurashtra. The studies from Bay of Bengal (3.2657)[34], the Arabian Sea (3.7169 in males and 3.4444 in females)[10] and the northwest coast of India (2.0279)[13] showed a thorough allometric growth in Bombay duck. The values of 'b' vary from 2.5 to 4 in fish[35] and the values of 'b' deviate from 3 in a more significant part of the situation. The female used to have a 'b' value that was more dominant than the male, which is similar to the previous research[19]. The 'b' values fluctuated from 2.9615 to 2.3686 in different types of the Hooghly estuary reported by Mitra[36]. in a comparative study, the isometric growth of *H. nehereus* was reported by observation with 'b' values of 3.051 and 2.889, separately from the Bay of Bengal[9] and the Arabian Sea[7]. Similarly, in the present test, the male exhibits an isometric growth pattern which correlates with the reported assertion that adult fish follow an isometric growth pattern[37].

Condition factor:

In the distinctive months of the year, the monthly K values for *H. nehereus* males and females displayed small differences. Overall, in the present investigation, the Kn value observed for the *H. nehereus* was 1.02 ± 0.21, showing the good physiological state and the general prosperity of the fish[38]. Unfavourable natural conditions (both abiotic and biotic) are the symbols with lower K values[39]. The highest mean value of Kn (1.11) was seen for males in October 2015 and February 2016, followed by a comparable value for females in May 2015. A similar result was reported by Krishnayya[34], where the highest Kn values of *H. nehereus* were observed in October (2.573) and the lowest in May (1.661). It should be noted that the stomach fullness was not examined before the analysis; therefore, it is not possible to relate the condition of fullness to the K values[40]. Moreover, fishes might be with empty stomach at the time of the research, even though they consume enough food to grow and survive in the marine habitat. The Kn values in females indicates an increasing pattern during September and October, this

might be due to a sharp impact on the growth of the metabolic strain, the ovarian state expended and the lower desirable species growth rate during November and the low value shown until the end of March[10].

The peak value of Kn (1.00) was found for 195 - 209 mm and 225 - 239 mm size groups in males and similar values were reported in female length groups of 225 - 239 mm and 315 - 329 mm. The mean Kn values for the size class were 1.05 for males and 1.06 for females. During the various periods of development and reproduction, the Kn values are determined to reflect differences in the fish state[41]. Due to the availability of nutrition, the differential feed rate, the size of the fish and the normal breeding season of the stock, fluctuations in Kn values are important for the fish[42].

It is accepted that differences in the K values of *H. nehereus* from various places and times originate from different elements, such as shifts in the oceanic condition as well as food accessibility. Anibeze[43] clarified that the unique K values in fish indicate the proximity of sexual maturity and the abundance of nutrients in a few species of animals. The increase in K values reflects a change in the nutritional status of fish, whereas dietary deficits are suggested by declining values[44]. Understanding the general state of Bombay duck showed that the enhancement of gonad and diet were the two key elements that contributed to the improvement in the status of the fishery.

Conclusion

The investigation of the analysis suggested that the length-weight relationship in the *H. nehereus* had differences in various time periods of the study. Overall, positive allometry was shown during the duration of the study. Contrasts in condition factor (K) and relative condition factor (Kn) for *H. nehereus* were noted. In addition, the selected species recorded reasonably high Kn values for the large size classes, which included the highest number of first-time spawners and expectations correlated with the rise in gonad status. This research provides vital knowledge on the growth of fish in various seasons, much as the state of the fishing situation may be useful in coping with aspects of fisheries within that jurisdiction.

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Conflict of Interest

The authors have no conflicts of interest to declare.

Author Contributions

MDF: Conceptualization, methodology, analysis and interpretation of data, and manuscript draft writing. PR: Scientific advisor, validation, technical editing and reviewed the manuscript draft.

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